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INFORMATION SHEET ON DEHYDRATED WHITE POTATOES*

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Bureau of Agricultural and Industrial Chemistry
Agricultural Research Administration
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Of all the vegetables that are being dehydrated, potatoes are the most important from the standpoint of production and demand. Requirements of dehydrated potatoes exceed those of other vegetables; in fact, the total present requirements of potatoes are almost equal to those of all other dehydrated vegetables combined.

Production

The production of potatoes in 1942 amounted to 11 million tons. Potatoes are grown in all States. Maine, with a production of 1.3 million tons, or 12 percent of the national total, led all other States. Idaho with 918,000 tons and New York with 822,000 tons were next in importance. Five other States--California, Minnesota, North Dakota, Pennsylvania, and Colorado--each produced over 500,000 tons. The entire production of these 8 States was more than half the total national crop.

Harvest Seasons

Potatoes are grown during all seasons of the year in one part of the country or another. In some of the Southern States, the harvest starts early in the spring, while in southern Florida and in the lower Rio Grande Valley of Texas potatoes are harvested toward the end of the year. Early potatoes are a relatively unimportant part of the total production. The season of availability for the intermediate and late crops extends from the beginning of the harvest to at least the late spring of the following year.

Yields

Yields per acre are influenced to a large extent by climate and the use of irrigation. Secondary but also important influences are cultural methods, varieties, fertility of soil, diseases, insect damage, and quality of seed. In regions where the crop matures during hot weather, there is often heat injury to the potatoes. In the South, where they are grown during the winter, freezing injury to the plant is common. Potato yields vary widely from year to year and among the States. The 1930-39 average yield per acre for all States was 3.4 tons, compared with 3.9 tons in 1941.

Varieties

For dehydration purposes many operators prefer the type that becomes white and mealy with cooking. A limited number of tests at the Western Regional Research Laboratory suggest the advisability of experimental testing of potatoes grown in any given area, prior to the establishment of a new dehydration plant, as a means

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of determining (1) the operating conditions that make the best dried product, (2) the acceptability of this product for use, and (3) the yield of dried product obtainable from the raw material.

The most widely grown variety of potato in the United States is the Irish Cobbler. Because of its remarkable adaptability, it is grown to some extent nearly everywhere. The Triumph potato is second in importance and acreage, with large concentrations in the Middle West. The Green Mountain group is important in Maine and the neighboring States. Production of the Russet Burbank group of varieties is concentrated entirely in the Northwest. In California, the White Rose is the leading variety. A new variety called Katahdin is fast acquiring importance in the East. Rural Russet and Rural New Yorker No. 2 are grown extensively in certain States in the region of the Great Lakes. The conditions under which these varieties are grown will affect their suitability for dehydration.

Storage

Only mature tubers, free from disease and bruises, should be stored. A storage temperature of 40°F. is low enough to keep mature potatoes dormant 3 to 5 months. At this temperature, however, they may become mildly sweet. If stored at 40°F. or lower the potatoes may show marked yellowing after being dehydrated, but upon reconstitution will be light yellow in color. For short-time storage, 50° to 60°F. results in good texture, color, and flavor in the cooked product. Potatoes stored at the lower temperatures should be held at 60° to 65°F. for 3 to 4 weeks just prior to dehydration. Under these conditions the sweet taste will be lost and a satisfactory dried product obtained. The relative humidity recommended for potato storage is 85 to 90 percent.

Potatoes can be stored in pits or large bins of 150 to 1,000 bushels in the Northern States, but in milder climates they should be stored in smaller units. Insulation and ample ventilation are needed to provide the best conditions for storage. Potatoes should always be stored in the dark because in the light they become green and unfit for food as a result of the development of solanine, a bitter poisonous substance.

In most districts potatoes are handled and stored in bags. After delivery to the plant measures must be taken to make sure that the crop will remain in good condition until used. Moreover, moderately cool temperature should be provided, in insulated rooms if necessary. The bags should be stacked to provide aeration and to prevent heating. When the weather becomes cold, heat should be provided to prevent freezing.

Since potato handling is almost an all-year job, maintenance of cool storage to reduce spoilage is important. Several days of warm storage, just prior to dehydration lightens the color and decreases the sweet taste.

Preparation

Thorough washing is the first step in the preparation of potatoes for dehydration. This operation can be carried out by running them through a revolving corrugated-drum or squirrel cage washer equipped with sprays. Following washing, grading to

size should be performed if abrasion or radiant-heat peeling is used, since grading speeds up the peeling operation and reduces waste. Other methods are lye and brine peeling.

Trimming is necessary after the peeling operation to remove the eyes and black spots or unsound or damaged portions that remain after the product has passed through the peeling machines. The total waste from peeling and trimming varies with the grade and size of the tubers, the peeling method used, and the care exercised in peeling and trimming. In commercial plants this waste is rarely lower than 15 percent, and may rise to 30 or even 40 percent if the raw material is inferior or the operation is conducted carelessly. With abrasive peeling the average overall loss is about 23 percent and the range 18 to 27 percent. With lye, brine, or heat peeling, the losses may be considerably less, as low as 12 percent. Results of recent investigations on brine peeling conducted at the Western Regional Research Laboratory are available on request.

The peeled and trimmed potatoes pass to mechanical cutters where they are cut into slices, cubes, or strips (julienne style) in accordance with the form desired. Current government specifications for dehydrated potatoes specify the following sizes of cuts:

Form	Thickness	Length
	Inches	Inches
Slices	2/16 - 4/16	---
Cubes	3/16 - 6/16	---
Strips	3/16 - 6/16	Not less than 3/4

After cutting, the potatoes proceed to a washer where the loose starch is removed. This operation is then followed by blanching. If delay between cutting and blanching is unavoidable, the cut material must be held under potable cold water, or a clean 2 percent salt solution. This procedure will protect the cut product from discoloration as the result of enzymatic oxidation. The material should not be thus held for more than one hour.

If the production of riced potatoes is contemplated, the peeled and trimmed potatoes can be quartered and then blanched, as discussed in the section below on blanching.

Blanching

The blanching of cut potatoes should be carried out in a blancher in which a high temperature is maintained by the introduction of live steam. The blanching time will vary, depending on many factors, namely: altitude, uniformity of heat distribution in the blancher, loading per square foot of loading surface, maintenance of high temperature, size of the pieces, and the characteristics of the raw material.

In order to meet the current government specifications, the material must be blanched until the peroxidase system is inactivated. The time required will vary from 4 to 10 minutes. The suggested blancher loading is approximately 4 pounds per square foot of surface.

After blanching, the material should be sprayed again with clean water in order to remove loose starch that might cause the pieces to stick together during dehydration. Delays between blanching and dehydration should be avoided. In any case, the material should not be held longer than one hour prior to dehydration. The quartered potatoes that are to be riced are blanched in live steam until cooked, usually for 20 to 25 minutes. After this operation and while still hot, they are passed through a mechanical ricer directly to the drying trays.

Dehydration

The moisture content of raw white potatoes varies with the variety, maturity, locality, and storage conditions. Since moisture content influences the yield of dry product, it is important for the operator to know the moisture content of the material to be used.

The approximate range in moisture content of raw potatoes is shown below, at the left. From these percentages the weight, in pounds, of water in potatoes per pound of "bone-dry" matter has been calculated and is shown also. The bone-dry matter must not be confused with the finished product, which contains a low percentage of moisture, as shown by the maximum percentages permitted under government specifications. The ratio of water to bone-dry matter in the raw product is useful to the operator because it shows him how much water is contained in the product and makes readily calculable the weight of water that must be removed.

Moisture in raw potatoes (percent)*		Lbs. water per lb. bone-dry matter		Moisture specifications (maximum percent)
Range	Av.	Range	Av.	
66.0-85.2	77.8	1.9-5.8	3.5	cut: 7.0-riced: 8.0

* From Chatfield and Adams: Proximate composition of fresh vegetables, U.S.D.A. Circular 146(1931). Tests at the Western Regional Research Laboratory have shown a higher average ratio of water to bone-dry matter--4 instead of 3.5 to 1.

The drying ratio, or its converse, the drying yield, can be calculated from the change in moisture content of the material in the drying step alone. The drying ratio is the ratio of the weight of material entering the dehydrator to the weight of the same material as it leaves the dehydrator commercially dry. The drying yield, usually expressed in percentage, is the reverse ratio of the same two weights. These ratios are useful in the design of dehydrators and for comparing the prospective yields of product from different types of raw material, since it may usually be assumed without serious error that the moisture content of the blanched, prepared material entering the dehydrator is the same as that of the raw vegetable. The following values of drying ratio and drying yield were calculated in that way from the moisture ranges given in the foregoing table, with the moisture content of the commercially dry product assumed to be 6 percent:

Drying ratio (lbs. entering dehydrator per lb. leaving it at 6 percent moisture)		Drying yield (percent)	
Range	Av.	Range	Av.
2.7-6.3	4.2*	15.7-36.2	23.6*

* The drying ratio and yield corresponding to the average moisture content of potatoes observed in tests at the Western Regional Research Laboratory (4 pounds per pound bone-dry) are 4.7 to 1, and 21.3 percent, respectively.

The operator is more directly interested in the overall shrinkage ratio, that is, the weight of unprepared raw product required to yield one pound of finished product which meets specifications. This may also be expressed as the reversed ratio, usually as a percentage, and is then known as the overall yield. The overall shrinkage ratio is always substantially higher than the drying ratio, and the overall yield lower than the drying yield, because all weight losses incurred at various steps of the process, such as culling, washing, peeling, trimming, and inspecting, must be discounted. Averages and ranges are not included here, because these other losses vary widely, as mentioned on page 3.

For the dehydration of riced potatoes, slices, strips, and cubes, the following tray loadings for different systems of air flow are suggested for trial:

Type of piece	Cross circulation of air	Through circulation of air	Finishing bin
	Lbs. per sq. ft. of loading surface		
Riced	1.0	2.0-3.0	A loading
Slices	1.0-1.3	2.0-3.0	depth of
Cubes	1.3-1.8	6.0-12.0	2 to 4 feet
Strips	1.2-1.5	6.0-12.0	is probably satisfactory

Variations between varieties and within a single variety due to maturity, cultural conditions, or storage conditions make it necessary to determine safe operating temperatures by trial. The general principle to be followed is that the finishing temperature shall be carried as high as possible without damage to the product. To serve as a guide the following temperature conditions for different systems of dehydration are suggested for trial:

Counterflow Tunnel

	°F.
Hot-end temperature - - - - - - - - - -	Not over 150
Wet-bulb depression at cool end - - -	At least 25

Parallel-Flow Predrier

	°F.
Hot-end temperature - - - - - - - - - -	200-220
Cool-end temperature - - - - - - - - -	Not over 160
Wet-bulb temperature - - - - - - - - -	Not over 120
Wet-bulb depression at cool end - - -	At least 30

Center Exhaust Tunnel

	°F.
Primary end	As in parallel-flow predrier
Secondary end	As in counterflow tunnel

Conveyor-Type Drier--Through Circulation

	°F.
Primary end, first section:	
Dry-bulb temperature	180-200
Wet-bulb temperature	Not over 120
Primary end, second section:	
Dry-bulb temperature	160
Wet-bulb temperature	100
Finishing end:	
Dry-bulb temperature	150
Wet-bulb temperature	90

Bin Finishing Drier

	°F.
Dry-bulb temperature of air entering drier	120-130 (at least 10° lower than finishing temperature in dehydrator)
Relative humidity	10 percent or less

Cabinet Drier

	°F.
Starting temperature:	
Dry bulb	200
Wet bulb	Not over 120
Finishing temperature:	
Dry bulb	150
Wet bulb	90-95

As drying in a cabinet progresses, the dry-bulb and wet-bulb temperatures are lowered by steps until the desired finishing temperature is reached. The temperature changes are made on the basis of a time schedule previously determined by a pilot run in which the temperatures are lowered in steps as the moisture content of the product is lowered. Since moisture is lost rapidly at first, the temperature must be lowered after a relatively short time interval. Further adjustments are made after gradually lengthening intervals. Fully a half of the total drying time should be taken at the temperatures given above as finishing conditions.

Each operator will have to depend upon the method of trial and error and experience to arrive at the proper conditions. The suggestions given above on cabinet drying will supply the operator with a starting point for the trial-and-error investigations. It should be remembered that the conditions suggested may not in all cases give the best results.

Packaging

The packing-room equipment and methods for dehydrated potatoes are typical of those required for other dehydrated vegetables that require protection from water vapor but not from air. A picking belt for the removal of defects, a

shaker screen for the removal of fines from cut potatoes, a jogging stand to increase the net weight per can or carton, and an over-and-under type of weighing scale are commonly used.

Tin cans have been replaced to some extent by 5-gallon square cartons as containers for dehydrated potatoes. The simplest equipment for these containers consists of an expanding mandrel, an overhanging shelf a little higher than a carton, a hand-operated, thermostatically controlled heat sealer, and carton assembling equipment. The product is first poured into an inner carton of chipboard. After adjustment to net weight, this carton is closed and the flaps are taped. The water-vapor protection is derived from a laminated, lead-foil bag which is opened on an expanding mandrel and slipped down over the inner carton; the "ears" of the envelope are smoothed down on the sides of the carton, and the carton and envelope are turned to bring the opening uppermost. Then the open end is flattened to a horizontal position above the overhanging shelf and the envelope is sealed with the sealing iron. The side seams are flattened; the upper ears are turned in over the top; a U-shaped piece of light chipboard is looped under the carton to protect the bottom and side seams when the filled package is placed in the outer carton. The latter is of solid weatherproof fiber and holds one 5-gallon unit.

More highly mechanized plants commonly use chutes, a suction nozzle to extract surplus air just at the time the envelope is being sealed, and a rotary heat sealer. The number of steps and the labor requirement are greater than for packaging in tin cans. A detailed description of this container can be found in the current tentative government specifications for dehydrated potatoes. Dehydrators will require between 250 and 380 5-gallon cartons for every 10 tons of raw untrimmed potatoes that are to be dehydrated.

Storage of Packaged Product

Dehydrated white potatoes are moderately sensitive to heat, being less susceptible than cabbage and more so than sweetpotatoes. It is a good general rule that all vegetables should be cooled to 90°F. or lower within 24 hours after they are dried. It cannot be assumed that all of the requisite cooling will take place while the material is exposed on the picking belt. Completion of the cooling to 90°F. will take place satisfactorily after the material is packaged if the packages are kept separate from others. The rate of cooling will be very much slower if the cartons are stacked in a compact pile; the cooling that will occur in an isolated carton in 7 hours will require 7 days in a compact double stack, and 7 weeks in a compact stack 4 cartons thick. On the other hand, close stacking of cooled cartons in large blocks lessens the rate at which heat will be absorbed. This fact can be used to advantage when the product is in transit through warm regions. The temperature of packaged material can be taken by placing a thermometer in the center of the carton and reading after 10 minutes.

Inspection and Specifications

Purchases of dehydrated vegetables for the several government agencies are inspected by the Fruit and Vegetable Branch of the Food Distribution Administration. Processing procedures are noted and the finished product is inspected for quality according to the specifications under which the purchase is made. Certificates are issued only when inspections are made on the sealed containers representing the shipment.

In order to facilitate inspection and as a direct aid to the manufacturer certain steps should be followed. The packaged material should be coded and warehoused by coded lots. The coding can follow any system desired but should impart the following information: Product, type, year, month, day, and shift.

Samples are drawn at the rate of approximately 1 container per 100 and representative samples are taken. The containers are checked for condition and the net weight determined by subtracting the tare weight from the gross. The entire contents are removed from the can and mixed thoroughly. A cross section is taken to make a composite sample and filled and sealed into previously dried jars. Examinations for defects, uniformity of size, presence of fines, and color of dry product can be made on the remainder and most of the material returned to the packer for repackaging.

Laboratory analyses are made to determine the moisture content, enzyme inactivation, reconstitution, and other factors as outlined in the specifications under which the product is being graded. Upon completion of the inspection the results are forwarded to the contractor and purchasing agency. Official certificates are issued and dated according to the date of the last day required to complete the analysis. These certificates serve as a basis for payment when the merchandise is received and accepted.

Purchases are made on Quartermaster Corps Tentative Specifications which are obtainable through the Chicago Quartermaster Corps, 1819 West Pershing Road, Chicago, Illinois, or Tentative FSC Specifications obtainable through the Fruit and Vegetable Branch of the Food Distribution Administration, U. S. Department of Agriculture.

It is suggested that dehydrators of potatoes pay special attention to the moisture content, peroxidase test, and defects due to heat and decay. (For the current moisture specification, see page 4.)

Reconstitution and Quality

The color and texture of reconstituted potatoes are influenced by the variety, growing environment, maturity, predrying storage, predrying preparation procedures, time and method of blanching, drying conditions, and methods of rehydration. Underblanched dehydrated potatoes will rehydrate slowly and incompletely. If overblanched, the pieces may disintegrate in part or entirely when rehydrated at boiling temperatures. The most unsatisfactory samples are those that partially disintegrate, forming a mush in the water while the centers of the pieces remain dry, hard, and chewy. It is assumed that cubes, strips, and slices are produced because the forms are desired for specific table preparations; the rehydration procedure should therefore preserve these forms. Samples of high quality will rehydrate successfully by boiling without previous soaking, but since table preparations such as fried, escalloped, and hashed browned are best when unboiled materials are used, the rate and completeness of rehydration at room temperature, as well as boiling, should be determined.

Because of the great number of factors that affect quality, some of which can be overcome by changing the conditions for rehydration, it is recommended that each producer conduct a series of tests for rehydration and quality on each lot of potatoes. An acceptable product should rehydrate to satisfactorily plump pieces without becoming mushy or watery. The rehydration ratio (the rehydrated weight divided by the dry weight) will vary with the size and shape of the piece, the time held in water, and the temperature of the water. In the table on page 9 are rehydration ratios obtained with high-quality samples at the Western Regional Research Laboratory.

Form	Size (in.)	Boiled without soaking 5 min.	10 min.	20 min.	Boiled after soaking overnight 5 min.	10 min.	20 min.	Soaked overnight, not boiled
Cubes	6/16	2-3	3-4	3-4	3-4	3-4	4-5	2-3
Slices	2/16	--	--	4-5	--	--	--	--
Strips	5/32	3-4	4-5	--	4-5	4-5	--	3-4

For the rehydration of cut potatoes, add 8 parts of water to one part by weight of the dried product and boil separate samples gently for 5, 10, and 20 minutes. Drain carefully through an 8-mesh strainer for 2 minutes. The rehydrated weight should be approximately 2 to 4 times the original weight of vegetable for diced or cubed, and 3 to 5 times for julienne strips. Soaking before boiling will give a plumper product and slightly greater drained weight in the larger pieces. Long boiling will cause deterioration in taste, flavor, and color. The reconstituted product should be free from sour or bitter taste, mild in potato flavor, and soft and tender in texture. The color should be a uniform yellowish white to pale yellow. The pieces should be whole and nearly perfect in form.

The addition of 5 to 7 parts of half-and-half milk and water to one part by weight of dried riced potatoes should yield a product with the normal consistency of mashed potatoes. If 4 parts of liquid yield a material thinner than is normal the dehydrated riced potatoes may be considered unsatisfactory. The material should be held in a double boiler for 30 minutes at room temperature, placed over boiling water for 10 minutes, or until heated throughout, and then whipped until light and fluffy. The whipped material should be reasonably free from lumps and should have a mealy texture. A product with a waxy or pasty consistency should not be accepted.

The vitamin content of freshly dehydrated potatoes will vary with the nature of the raw product and with the conditions of preparation and drying. The results of a number of tests made at the Western Regional Research Laboratory indicate that an ascorbic acid content of 15 to 40 mg. per 100 grams of freshly dried potatoes may be expected.

For further detailed information address the Western Regional Research Laboratory, Albany, California, or the Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, Washington, D. C.

(Certain portions of the material presented above were supplied by the Bureau of Plant Industry, Soils, and Agricultural Engineering, and Oregon State College.)